INFLUENCE OF BASSWOOD ON THE FOREST GROWING PROPERTIES OF SOIL

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It is an established fact that basswood in a coniferous forest improves the forest-growing properties of the soil (4, 2, 15, 13)[2]. However, little is known at present of the effect of basswood on soil formation in a broadleaf forest. Some information on this problem can be found in the works of Shumakov (8, 9), who notes that a dark-gray clay loam under a 22-year old basswood plantation is somewhat richer in humus, exchangeable bases, and available phosphorus compounds, has a higher general biochemical activity, but less favorable conditions of nitrogen nutrition than the same soil under an oak plantation. We must also mention the investigations of Grishin (2) who, on the basis of certain differences between the structural profile and properties of sod-weakly podzolic soil under a basswood forest and the same soil under an oak forest under the same conditions, concluded that the replacement of an oak plantation by a basswood plantation increases the productivity of soils.

Observations in the Voronezh Reservation showed that when basswood is grown in an oak forest the chemical and physico-chemical properties of the soil improve noticeably. It was found that the upper soil horizons are rich in humus, exchangeable bases, and available potassium and nitrogen compounds under a strip of basswood saplings. These horizons have a less acid reaction, a lower exchange and hydrolytic acidity, and a higher degree of base saturation than the upper horizons of soils under strips of oak. Ammonification and nitrification are more strongly developed in the soil under basswood. No noticeable differences were found in the properties of the B_1 and B_2 horizons in the soil under oak and the soil under basswood. These observations were made in a basswood-oak forest on gray-brown sandy soil underlain at a depth of 2 m by clay loam. The composition of the plantation was 6 oaks, 2 basswood, maple aspen, 90-100 year old stand, and has a density of 0. 8. Basswood formed the I and II stories.

Trees influence the soil through the lead-fall and through the root system. We know that basswood leaves are considerably richer than oak leaves in such important nutrients as nitrogen, calcium, potassium, and magnesium. Our data completely agree with this (Table 1).

The higher content of nutrients in the basswood leaf-fall must undoubtedly play a primary role in the enrichment of the soil in these elements under areas of basswood. However, in addition to composition of tree leaves, the nature of its decomposition plays an essential role in soil productivity.

The rate of nutrient liberation determines the possibility for plants to use them a second time within one year. The rate of nutrient liberation at various periods can be either more or less favorable to a plantation. It is favorable when the most intense liberation of nutrients coincides with the time of their maximum uptake by the trees. Negative results are obtained when nutrients are liberated from the litter during warm spells in winter when the uptake of mineral elements by the plants is very low and these elements may be lost without return when removed from the soil.

Since the dynamics of litter decomposition and leaching determines to a considerable degree the nature of the influence of trees on the soil, we studied the mineralization of the litter from basswood, oak, and a mixture of these two. We thought that the study of this process would uncover one of the reasons for the positive effect of basswood on the soil of oak forests.

Comparative data on the decomposition rate of basswood and oak leaf-fall are available in the literature. Using different methods of study, Stepanov (12), Wittich (17), Utenkova (14), and Slovkovskiy (10) found that the rate of mineralization of basswood leaves was greater than that of oak leaves. Utenkova also established a pattern in the course of decomposition and nutrient liberation of leaves from these two types of trees. However, the material obtained by the foregoing authors is far from being exhaustive, especially with respect to the dynamics of mineralization and leaching.

The experimental part of the present study was conducted at the Voronezh Reservation according to the following method. Büchner funnels, 20 cm in diameter and placed at soil level in a spot in the forest, were filled with

[1]The work was conducted under the supervision of N. P. Remezov.

[2]The bibliography has been arranged in the Roman alphabet, editors.

Table 1

Content of nitrogen and ash elements, % of leaf-fall dried at 100°C

Leaf-fall	N	Ca	K	Mg	P
Basswood	1.55	2.53	0.67	0.53	0.24
Oak	1.33	1.39	0.59	0.41	0.24

40 g of freshly-fallen oak and basswood leaves, and oak leaves with a small amount of basswood leaves (5% of weight). The leaf-fall was inoculated with its inherent microflora by pouring a small amount of water suspension from the oak-basswood forest litter into each funnel. Solutions forming during rain and snow melting drained into glass collectors set in a trench. The experiment was started in November 1958, and repeated with certain modifications in November 1959. In 1959 we used lysimeters 20 x 40 cm in area and 10 cm high made of galvanized iron, instead of the funnels, coated with bituminous lacquer. The mixed sample consisted 35% of basswood leaf-fall. The weight of the leaf-fall in each lysimeter was 100 g.

Experimental conditions differed essentially from natural conditions. The litter did not decompose at the soil surface, but directly at the bottom of the lysimeters which were covered with a sieve with openings 2 mm in diameter. The edges of the lysimeters were raised above the soil level. All this almost excluded the possibility of mesofauna falling into the litter. The effect of the microflora was also reduced.

At the same time experiments were made under conditions more closely approximating natural conditions. In the autumn of 1958 caprone bags were filled with a few grams of fallen oak and basswood leaves and placed on the soil surface in the basswood-oak forest. The bags had many holes through which worms, insects, and other animals could penetrate. A year later the content of the bags was weighed.

In addition to the lysimeters described earlier, lysimeters with a soil layer at the bottom were also used in 1959. This soil layer, 5 cm thick and with an undisturbed structure, was cut from the A_1 horizon of the soil in the basswood-oak forest. The leaf-fall was placed on top of it and consisted of: 1) basswood leaf-fall; 2) a mixture of 35% basswood and 65% oak leaf-fall; 3) a mixture of 23% basswood and 77% oak leaf-fall; and 4) oak leaf-fall. Each treatment was replicated three times. Moreover, three lysimeters were left without litter. The composition of the mixtures corresponded to the relative content of basswood and oak leaves in the litter collected under basswood and oak areas in the autumn of 1959. As we can see, oak leaves predominated in the litter under both types of forest areas and the proportion of basswood leaves only increased under the basswood area.

The results of the experiments (Table 2) showed that leaf-fall isolated from the soil decomposes much more slowly than that lying at

Table 2

Decrease in the weight of the decomposing litter, % of initial amount

Leaf-fall	1958		1959	
	in Büchner funnels	in caprone bags	in lysimeters, without soil	in lysimeters, with soil
Basswood	37,0	60,0	35,4	61,6
Mixed	25,6	—	33,2	49,9
Oak	15,7	27,0	27,7	39,5

Note: Comma represents decimal point.

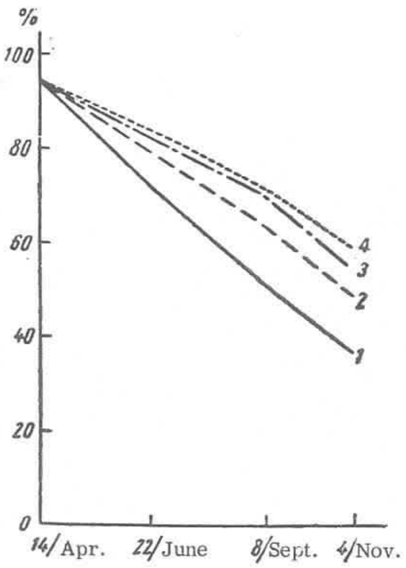
the soil surface. From 1.6-1.8 times more vegetative matter decomposed in the caprone bags than in the Büchner funnels. Leaf-fall placed in lysimeters with soil lost 1.4-1.7 times more weight than leaf-fall in lysimeters without soil.

It must be noted that approximation of natural conditions of decomposition, i.e., increasing the participation of the fauna and microflora in the reworking of the leaves, reflects more on the rate of decomposition of basswood leaves than on oak leaves. This is the natural result of the fact that worms, polypods, and other representatives of the soil fauna behave selectively toward tree leaves, according to the investigations of Zrazhevskiy (19), Wittich (17, 18), and others, and more readily rework the tender basswood leaves than the coarse oak leaves.

The results of our experiments confirmed the assumption that basswood leaves decompose more intensely than oak leaves (Table 2). At the end of a year the loss in the weight of basswood leaf-fall exceeded that of the oak leaf-fall 1.5-2 times. The results of the experiment started in 1958 appear to indicate that basswood leaves have an accelerating effect on the decomposition of oak leaves, since a 5% admixture of basswood leaves increased the decomposition rate of the leaf-fall 1.5 times. But this was not confirmed by the experiments of the following year. Oak leaves mixed with basswood leaves decomposed at the same rate as oak leaves in a pure oak leaf litter.

A year's study of the change in the weight of leaf-fall in lysimeters with soil showed that the course of decomposition of basswood leaves differs from that of oak leaves (Fig. 1). During the winter the loss of weight of both types of leaves was 5%. We were unable to determine more accurately the loss of weight of each type of leaves.

The decomposition of basswood, oak, and mixed leaves was considerably more intense in spring and summer than in winter. The decomposition rate remained almost unchanged during the growing period. The decomposition rate of basswood leaves decreased somewhat in autumn, while oak leaves and oak leaves with an admixture of basswood leaves decomposed more intensely.



Similar results were obtained in 1958-1959 with the leaf-fall in Büchner funnels. Twenty-nine percent of the basswood leaves decomposed from mid-April to the end of August and another from mid-April to the end of August and another 5.6%, by the end of November. At the same time only 7% of the oak leaves decomposed during spring and summer, and 6.5% during the three autumn months. Evidently Wittich (17) is right in that the reworking of coarse leaves, or leaves containing substances repulsive to soil

Fig. 1. Dynamics of the weight of the leaf-fall (in % of the initial sample)

1 - basswood leaf-fall; 2 - mixed leaf-fall of basswood and oak, 35:65; 3 - mixed leaf-fall of basswood and oak, 23:77; 4 - oak leaf-fall.

animals, begins only after the more tender leaf is reworked and after harmful substances are removed from the leaves with less favorable properties as a result of the activity of microorganisms and water.

We studied the dynamics of the content of certain ash elements and nitrogen in the leaf-fall decomposing on the soil surface in lysimeters. For this purpose we determined the content of the elements in the leaves during

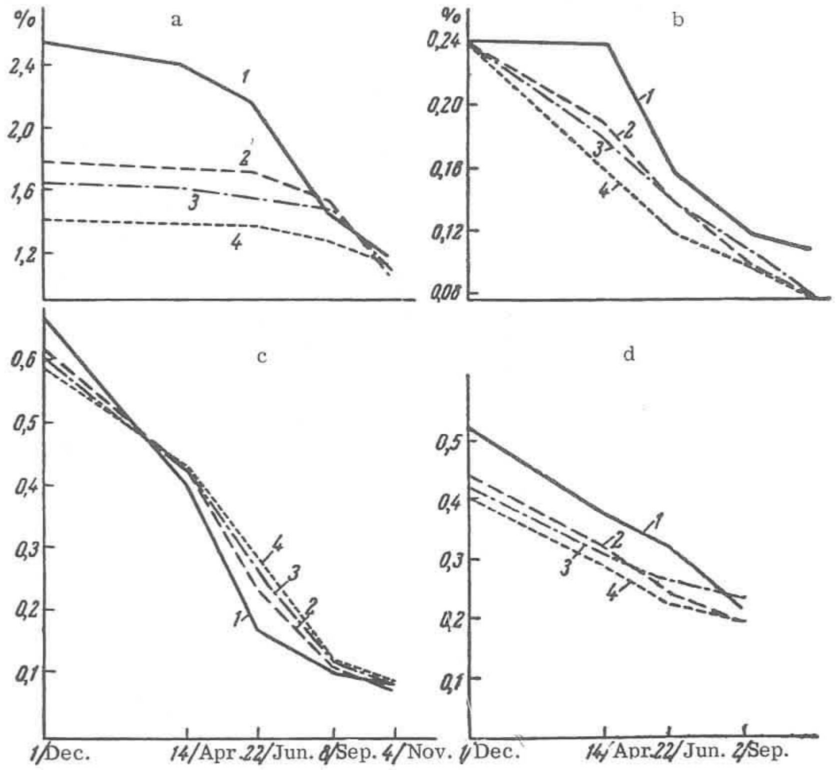


Fig. 2. Dynamics of the content of certain nutrients in the litter (% of initial leaf-fall sample dried at 100°C)

a - calcium; b - phosphorus; c - potassium; d - magnesium (for designations see Fig. 1).

various stages of its mineralization. The rate of leaf decomposition at definite stages exceeds the rate with which nutrients are removed (especially calcium and nitrogen) and in some cases we observed an increase in the percentual content of these elements during the process of decomposition. In order to judge of the actual loss of nutrients from the decomposing leaf-fall, their content at each stage of mineralization was calculated in percentages of the initial sample, i.e., the leaf-fall sample at the beginning of the experiment (Fig. 2).[3]

As far as the relative mobility of nutrients in the leaf-fall is concenred, our data agree with the results obtained by Utenkova (14). These elements may be arranged in the following series according to the ease with which they are removed from the decomposing litter: K > P = Mg > Ca > N. Our data make it possible to specify the periods when nutrients are liberated from the leaves.

After leaching by meltwater, the potassium content in the leaf-fall diminishes by 25%-40%. Under the same conditions basswood leaves lose more potassium than oak leaves. The maximum amount of potassium is leached during the growing period. A considerably greater amount of potassium is removed from the basswood leaf-fall during the first half of the growing period, and somewhat more potassium is removed from the oak leaf-fall during the second half of the growing period. The removal of potassium from the mixed leaf-fall is more uniform during the entire growing period. By the end of a year 85%-90% of the entire potassium are leached from the leaf-fall.

The maximum amount of potassium entering the soil in late spring and in the first half of summer best satisfies the requirement of woody plants for it, since intense foliage development occurs during this period, requiring a continuous supply of potassium.

The next most readily mobile nutrient in the oak leaf-fall is phosphorus and in the basswood leaf-fall, magnesium. Two thirds of the total amount of phosphorus was leached from the oak leaves within a year, and about half, from the basswood leaves. The differences were especially sharp in spring when the phosphorus content in the basswood leaf-fall remained unchanged, while it decreased by 33% in the oak leaf-fall. Such a difference is attributable in part to the biological absorption of phosphorus by micro-organisms which are more numerous in the basswood leaves. This phenomenon had also been noted by Kravkov (3). Apparently, the major reason from the greater mobility of phosphorus in the oak leaves is the great mobility of organic compounds which include phosphorus. The increased content of calcium and aluminum in the basswood leaves and the alkaline reaction of its filtrates correlate with the lesser mobility of phosphorus.

Since phosphorus compounds are not readily removed beyond the upper soil horizon, as we shall see later, the liberation of phosphorus from the oak leaves in winter and early spring creates more favorable conditions of phosphorus nutrition at the beginning of the growing period. By the end of June the soil receives 1.5 times more phosphorus from the oak leaf-fall than from the basswood leaf-fall.

Magnesium is more mobile from the basswood leaves than phosphorus. Sixty-five percent of the total amount of magnesium was removed as early as the beginning of September from the basswood leaf-fall, while half of it was removed from the oak leaf-fall. Meltwater removed 25% of the magnesium from the leaf-fall of both types of trees.

According to our data, the least mobile element (with the exception of nitrogen) is calcium. After meltwater had filtered through the basswood leaf-fall, only 5% of the calcium contained in it was lost, while its content in the oak leaf-fall remained unchanged. The liberation of calcium was very slow during the first half of the growing period, even from the basswood leaf-fall. This process accelerated considerably during July and August and slowed down somewhat in autumn. By the end of the year the soil had received slightly more than half of the calcium contained in the basswood leaf-fall. Oak and mixed leaf-fall began to lose calcium noticeably only in the autumn as decomposition began to accelerate. As a result, the calcium content in the oak leaves decreased only by 20% throughout the year. Evidently, the earlier and more intense liberation of calcium from the linden leaf-fall has a great positive effect, accelerating the cycle of this element in the soil-forest system.

The nitrogen content in the leaf-fall changed least during the year. It remained practically unchanged to the end of June and even increased by 2%-4% in two cases. The low mobility of nitrogen is due to its secondary biological fixation by microorganisms. It is also possible that nitrogen-fixing micro-organisms increased the nitrogen content somewhat. During the second half of summer the basswood leaf-fall lost considerable amounts of nitrogen, while the oak leaf-fall and the mixed leaf-fall became considerably poorer in nitrogen only in autumn as a result of the increased decomposition intensity.

Thus, during the first year of decomposition basswood leaves yielded considerably more nutrients to the soil than oak leaves and at earlier dates. The only exception is phosphorus. According to the periods of decomposition and the nature of leaching, mixed leaf-fall occupies an intermediate place between oak and basswood leaf-fall. Sometimes there is a clear dependence between the course of nutrient leaching and the composition of the mixture. However, this relationship cannot always be traced, probably because of the difficulty of taking average samples from mixed leaves.

The patterns described previously were also

[3] The plant material was calcinated by dry combustion. Calcium and magnesium were determined trilonometrically, and potassium, photometrically. Phosphorus was determined colorimetrically by the Denizhe method, and nitrogen, by the Kjeldahl method.

reflected on the dynamics of the chemical composition of water filtering through the leaf-fall decomposing at the bottom of lysimeters without soil (Fig. 3).[4] Let us note that the pH of lysimetric water was in all cases close to seven and did not drop below 6.2 and increase above 7.3. We found no regular changes in the pH from period to period or from type of leaves to type of leaves, except for the fact that filtrates from lysimeters with oak leaf-fall were consistently slightly more acid than the others.

[4]Ash elements in lysimeter water were determined by the same methods as in the plant material. Phosphorus was determined after igniting the organic matter.

The dynamics of the leaching of nutrients was generally similar in 1959 and 1960. The greatest differences occurred in the removal of nutrients in the second half of summer. This period was characterized by extreme dryness in 1959. Leaf-fall decomposed very slowly and the rains in August leached insignificant amounts of these elements from the leaf-fall. The concentration of the solutions was very low. There were constant rains during the second half of the summer of 1960, leaf-fall decomposition

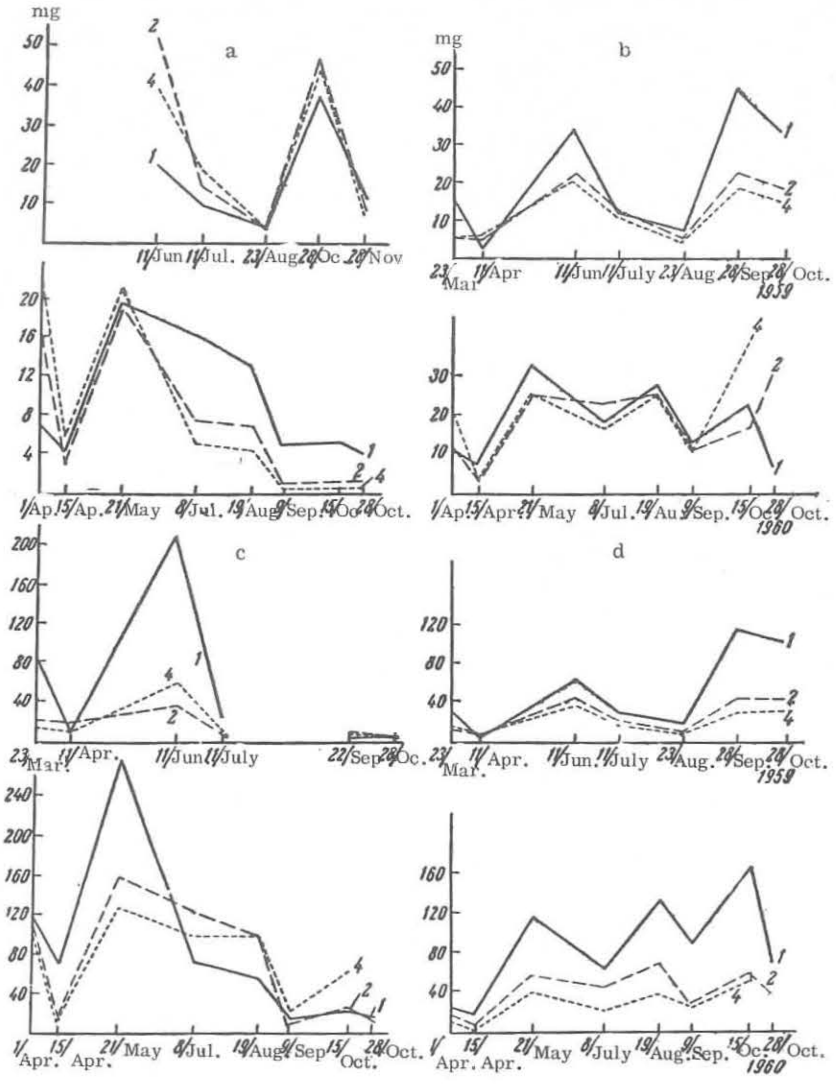


Fig. 3. Dynamics of the content of certain nutrients in lysimeter water (mg/100 g of leaf-fall).

a - phosphorus; b - magnesium; c - potassium; g - calcium (for designations see Fig. 1).

was rapid, and in July and August the collectors received a large quantity of leaching products. The concentration of the solutions was high. In spite of the differences in weather conditions, the leaching of nutrients in the summers of 1959 and 1960 followed the general patterns. Thus, the maximum leaching of potassium occurred in May-June; the leaching of calcium reached its maximum in autumn; phosphorus was more intensely liberated from the oak leaf-fall at the beginning of the growing period and from the basswood leaf-fall, in the second half of the growing period; there were two peaks in the leaching of magnesium, at the beginning of summer and in autumn.

We attempted to determine the nature of the interaction between the soil and solutions coming from the leaf-fall (in lysimeters with soil). Some authors, such as Shumakov (7), Zonn and Aleshina (18), and Smirnova (11), compared the composition of solutions draining from lysimeters filled with litter with the composition of solutions from lysimeters filled with soil and the same litter in order to determine the nature of the effect of the products of litter decomposition on the soil.

As we have mentioned earlier, experiments in the Voronezh Reservation showed that leaf-fall decomposes twice as fast on the soil surface than directly on the bottom of a lysimeter. Therefore, we found it impossible to come to a conclusion on the effect of solutions on the soil on the basis of the foregoing method. Instead, we compared the content of certain nutrients in the solutions draining from a lysimeter containing leaf-fall + soil with the decrease of these elements in the leaf-fall decomposing in the same lysimeter.

All the conclusions derived from this comparison are strictly qualitative. Rain water, filtered through the litter and the soil layer in the lysimeter, contained considerably more nutrients than water which would have filtered through the same layer in the forest. The primary reason for this is that lysimeters do not contain vegetation which would have absorbed nutrients from the solutions filtering through the soil.

In Remezov's studies (5) it has been established that the removal of nutrients beyond the profile of gray-brown sandy soil underlain by clay loam at a depth of 1 m - 2 m is relatively small under conditions prevailing in the Voronezh Reservation. Thus, on the average, not more than 3 kg/ha of calcium, and not more than 0.1-0.7 kg/ha of potassium are removed in a year, while the amount of phosphorus remains practically the same. According to the data presented in the present paper, up to 120 kg/ha calcium, up to 100 kg/ha potassium, and about 6.5 kg/ha phosphorus are removed from the upper 5 cm of the soil with leaf-fall. According to Remezov and Bykova's (6) data, the uptake of these elements by an oak forest of medium age is: 140 kg/ha of calcium, 64 kg/ha of potassium, and 20 kg/ha of phosphorus. It must be noted that about 90% of the feeding roots of oak and its companions are concentrated in the upper 5 cm of the gray-brown soil of the Voronezh Reservation (1). Consequently, a very large portion of nutrients is derived by the forest from this horizon which is being constantly enriched at the expense of the decomposing leaf-fall, the tops and roots of grass vegetation, and the roots of trees and shrubs. This horizon apparently plays the major role in the retention of nutrients in the profile of sandy soil by biological, as well as physico-chemical, and other types of absorption.

Comparison of the data on the magnitude of removal from the upper soil layer, bare of vegetation, with Remezov's data on the magnitude of removal from the entire soil layer, shows how important the role of the biological absorption of elements is in the creation and preservation of soil productivity.

Another reason for this extensive removal in our experiment is the decomposition of fine tree roots and, especially, grass roots in the soil of the lysimeter. The decomposition cut and dead roots yielded nutrients in mobile form to the soil. It is possible that the unusually high content of potassium in the filtrates from lysimeters containing soil + leaf-fall was associated with the decomposition of the grass roots rich in potassium.

These considerations make it very difficult to derive any definite conclusions from the results obtained. These results (Table 3) are the following:

The 5 cm thick humus horizon of sandy soil retains a considerable part of water-soluble organic matter yielded from the leaf-fall. This can be judged by the oxidizing capacity of solutions filtered through the leaf-fall, which is almost twice the oxidizing capacity of solutions draining from lysimeters containing soil + leaf-fall.

Since most of the phosphorus of the filtering solutions (as shown by direct determinations) is in the form of organic compounds, it is strongly retained by the soil. The absorption of water-soluble organic matter and phosphorus by the soil is apparently associated with the activity of micro-organisms. There was also a considerable absorption of magnesium during the winter-spring period.

As far as potassium and calcium are concerned, they were lost in considerable amounts from the soil during the year. Thus, almost twice as much potassium was leached from lysimeters containing leaf-fall + soil as was received from the leaf-fall. Such high removal of potassium and calcium results, as was mentioned earlier, from the lack of biological absorption of these elements and their liberation from the decomposing roots. The nature of calcium removal from the soil under basswood leaf-fall differs essentially from that under oak leaf-fall. Basswood leaf-fall yielded considerably more calcium at all times than the oak leaf-fall, while approximately the same amount or slightly more was leached from the lysimeter containing soil + basswood leaf-fall than from the lysimeter containing soil + oak leaf-fall. As a result, a certain portion of calcium leached from the basswood leaf-fall was retained by the soil in spring and in the first half of summer. During the same period, soil under the oak leaf-fall lost a considerable amount of calcium.

Table 3

Interaction between solutions from the leaf-fall and the soil

Soil studied	1959—1960			1980											
	Dec. 1, 1959-Apr. 15, 1960			April 16 — June 22			June 23 — Sept. 4			Sept. 5 — Oct. 23			For the entire year		
	1[a]	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Calcium															
Without leaf-fall	—	132	—132	—	112	—112	—	403	—403	—	143	—143	—	791	—791
With basswood leaf-fall	115	105	+10	165	140	+25	337	493	—156	120	200	—80	737	938	—201
With mixed leaf-fall, 35:65	33	90	—67	15	165	—150	117	428	—311	251	176	+75	416	859	—443
With mixed leaf-fall, 23:77	25	89	—64	40	145	—105	53	368	—315	237	172	+65	355	774	—419
With oak leaf-fall	7	110	—103	1	195	—194	67	302	—235	89	144	—55	164	751	—587
Potassium															
Without leaf-fall	—	142	—142	—	116	—116	—	151	—157	—	57	—57	—	466	—466
With basswood leaf-fall	265	199	+66	157	168	—11	44	337	—293	7	109	—102	473	814	—341
With mixed leaf-fall, 35:65	195	175	+20	132	178	—46	72	343	—271	20	102	—82	419	798	—379
With mixed leaf-fall, 23:77	180	135	+45	113	163	—50	90	286	—196	23	118	—95	406	702	—304
With oak leaf-fall	156	160	—4	98	172	—74	107	228	—221	20	98	—68	381	658	—277
Phosphorus															
Without leaf-fall	—	12	—12	—	7	—7	—	13	—13	—	.5 8	—5	—	37	—37
With basswood leaf-fall	0	11	—11	63	8	+55	23	19	+4	5	9	—3	91	44	+47
With mixed leaf-fall, 35:65	53	15	+38	35	11	+24	21	21	0	14		+5	123	57	+66
With mixed leaf-fall, 23:77	57	19	+38	35	10	+25	17	18	—1	16	10	+6	125	58	+67
With oak leaf-fall	78	14	+64	29	11	+18	14	16	—2	11	5	+6	132	45	+87
Magnesium															
Without leaf-fall	—	31	—31	—	21	—21	—	79	—79	Not determined			—	160	—160
With basswood leaf-fall	155	31	+124	40	32	+12	67	118	—51	"			262	231	+31
With mixed leaf-fall, 35:65	129	24	+105	53	30	+23	29	87	—58	"			211	184	+37
With mixed leaf-fall, 23:77	119	24	+95	35	31	+4	18	79	—61	"			172	173	0
With oak leaf-fall	110	38	+72	47	39	+8	46	61	—15	"			203	175	+28

[a]1 — from the leaf-fall (mg/lysimeter); 2 — from the lysimeter with soil and leaf-fall (mg/lysimeter); 3 — difference between the solution from the leaf-fall and from the lysimeter with soil and leaf-fall (mg/lysimeter); + retained by the soil; — leached from the soil.

At the end of the year soil under basswood leaf-fall lost three times less and that under mixed leaf-fall, 1.5 times less calcium than the soil under oak leaf-fall. Soil under mixed leaf-fall containing a large amount of basswood leaves lost relatively less calcium.

Consequently, the more calcium saturated the solution filtering throug the soil was, the less calcium was lost by the soil.

The low calcium content in the meltwater has a negative effect since it leads to the impoverishment of the soil in this element.

This large removal of calcium from the soil under oak leaf-fall is apparently due to the more acid reaction of the solution draining from it.

Thus, study of the course of decomposition of oak, basswood, and mixed leaf-fall showed that the decomposition of basswood leaves ensures a more favorable nutrition regime in the forest. The maximum yield of potassium during leaf development is of great positive effect.

The release of considerable amounts of magnesium, calcium, and nitrogen in the first year of decomposition accelerates the cycle of these elements and widens the possibility of a plantation of using these nutrients. The early release of bases and nitrogen promotes the creation of a neutral soil reaction and provides better conditions for bacterial flora. This is of great importance to the formation of mild humus which is associated with soil productivity under a broadleaf forest.

It must be emphasized that the high calcium content in solutions draining from basswood leaf-fall promotes the preservation of this element in the soil during winter and early spring when the root systems of trees do not take it up.

As a result of the slower release of phosphorus from the basswood leaf-fall, the soil, at the beginning of the growing period is not as well provided with this nutrient as in an oak forest.

When mixed with oak leaf-fall, basswood leaf-fall retains all its decomposition characteristics. A mixed leaf-fall creates more favorable conditions for the supply of the forest with potassium, calcium, nitrogen, and magnesium than an oak leaf-fall and a better phosphorus nutrition regime than a basswood leaf-fall.

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BIBLIOGRAPHY

1. BORISKINA, YE. M. 1959. Interaction between the root systems of oak and pine with soil. Tr. Voronezhsk. gos. zapovedn. No. 8.

2. GRISHIN, P. V. 1956. Soils of the Raif forest recreation area. Uch. zap. Kazansk. un-ta. Vol. 116, Book 9.

3. KRAVKOV, S. P. 1908. Material for the study of the processes of decomposition of plant residues. St. Petersburg.

4. REMEZOV, N. P. 1961. Soils of pine forests in the forest-steppe and in the southern forest regions. Pochvovedeniye. No. 5.

5. REMEZOV, N. P. 1958. Relation between biological accumulation and eluvial processes under forest cover. Pochvovedeniye. No. 6.

6. REMEZOV, N. P. and L. N. BYKOVA. 1952. Requirement and cycle of nutrients in an oak forest. Vestn. Mosk. un-ta. No. 6.

7. SHUMAKOV, V. S. 1941. Dynamics of decomposing plant residues and interaction between the products of its decomposition and forest soil. Tr. VNIILKh. No. 24, Vol. 1.

8. SHUMAKOV, V. S. 1954. Dynamics of certain properties of dark-gray forest soils under various types of forest plantations. Tr. In-ta lesa. Akad. Nauk SSSR. Vol. 23.

9. SHUMAKOV, V. S. 1960. Biochemical activity of dark gray forest-steppe soil under various forest plantations. Pochvovedeniye. No. 10.

10. SLOVIKOVSKIY, V. I. 1958. Problem of the decomposition and leaching of tree leaves. Dokl. Akad. Nauk SSSR. Vol. 119, No. 6.

11. SMIRNOVA, K. M. 1960. Study of the composition of lysimeter water under a spruce forest. Papers presented by Soviet soil scientists at the VII Congress of Soil Science in the U. S. A. Moscow.

12. STEPANOV, N. N. 1940. Mineralization of leaves and needles shed by trees and shrubs. Pochvovedeniye. No. 9.

13. TRAVNIKOVA, L. S. 1959. Influence of the basswood population in an oak pine forest on soil properties. Tr. Voronezhsk. gos. zapovedn. No. 8.

14. UTENKOVA, A. P. 1959. Results of a study of the decomposition of leaf-fall in an oak forest. Tr. Voronezhsk. gos. zapovedn. No. 8.

15. VINOKUROV, M. A. and P. V. GRISHIN. 1954. Influence of the replacement of basswood spruce forests by goutweed basswood forest on soil formation. Uch. zap. Kazansk. un-ta. Vol. 114, Book 1.

16. WITTICH, W. 1943. Untersuchungen über den Verlauf der Streuzersetzungen auf einem Boden mit Mullzustand. II. Forstarchiv, Jahrgang. H. 1, 2.

17. WITTICH, W. 1953. Untersuchungen über den Verlauf der Streuzersetzungen auf einem Boden mit starker

Regenwurmtätigkeit. Schriftenreiche Först, Fak. Univ. Göttingen. No. 9.

18. ZONN, S. V. and A. K. ALESHINA. 1953. Problem of the decomposition of leaf-fall in oak forests and the interaction between its ash elements and soils. Tr. In-ta lesa. Akad. Nauk SSSR. Vol. 12.

19. ZRAZHEVSKIY, A. M. 1956. Soil invertebrates as a factor in the biological cycle of substances in forest soil. Summary of papers presented at the Conference of Forest Soil Science at the Forest Institute of the Academy of Sciences of the Ukrainian SSR. Kiev, Izd. Akad. Nauk UkSSR.